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MANAGER EXAMINATION SUPPORT AND SALES

AUSTRALIA

PATENTS ACT 1990

PROVISIONAL SPECIFICATION

FOR THE INVENTION ENTITLED:-

"MULTICORE MICROSTRUCTURED OPTICAL FIBRES FOR IMAGING"

The invention is described in the following statement:-

FIELD OF THE INVENTION

The present invention relates to the design and manufacture of microstructured optical fibres. The invention has particular application in the manufacture of microstructured optical fibres for imaging purposes such as, for example, endoscopy, ear-implants, and chip-to-chip interconnects.

BACKGROUND TO THE INVENTION

In existing multicore fibres, light is guided through total internal reflection in cores of relatively high refractive index. Consequently, the imaging fibre has always been made from transparent material. The fabrication methods include stacking of capillaries and rods to make a preform, on bundling fibres, on complex doping techniques, or on co-extrusion. However, one of the difficulties encountered with these methods is maintaining the coherency of the fibre bundle and achieving adequate control over the position and size of individual cores (pixels), as well as obtaining a high capturing fraction.

It is therefore an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

SUMMARY OF THE INVENTION

To this end, a first aspect of the present invention provides a method is producing a microstructured optical fibre from a preform wherein zones of material of relatively high refractive index are positioned at predetermined locations within material of relatively low refractive index. In this way a pattern of guiding core material is created. The preform is subsequently drawn to create a length of microstructured optical fibre.

Preferably, each core is surrounded substantially by air, and connected by thin strands of fibre material. This enables the cores to guide independently (provided the strands are thin enough) and thereby provide imaging capability. The cores may be either single moded or multi moded. The cross-sectional shape of the cores is generally non-circular.

A second aspect of the present invention provides a method of producing a microstructured optical fibre wherein hollow channels, or channels of relatively low refractive index material, are positioned at predetermined locations in a preform. The preform is subsequently drawn to create a length of microstructured optical fibre in which the low-index channels can guide light independently based on the 'antiguiding'

effect as described in ["Identifying hollow waveguide guidance in air-cored microstructured optical fibres", N A. Issa, A Argyros, M A. van Eijkelenborg, J Zagari, Optics Express Vol. 11, No. 9, pp. 996-1001 (2003).]

Advantageously, the method according to the second aspect of the invention allows for the manufacture of relatively simple interconnects and imaging fibres with a high capture fraction.

Preferably the fibre is drawn from a monolithic perform. This provides enhanced control and stability over the resulting fibre.

Advantageously, a combination of the first and second methods of imaging is also possible in certain circumstances, which would provide the largest possible capture fraction (since it uses both the low index channels and the high index cores for the imaging). This enhances the pixel resolution.

A third aspect of the present invention provides a micro-structured optical fibre which includes air channels, said air channels acting to define light guiding cores between the air channels.

A fourth aspect of the present invention provides a micro-structured optical fibre for imaging applications, said optical fibre including air channels which act as light guiding cores.

In this embodiment of the invention, the fibre may include non-transparent materials.

Advantageously, the present invention provides a relatively simple method of producing a microstructured optical fibre for imaging applications and which allows greater control over the positioning and sizing of the cores. Any pixel arrangement is generally possible, both in terms of symmetry (hexagonal, rectangular etc) and in terms of core dimensions (multiple core sizes in one fibre are possible), making it relatively easy to tailor the characteristics of the imaging fibre. In addition, the cores (whether they are of relatively high or low refractive index) need not all be of the same dimensions. Cores, or groups of cores, can be individually sized to specific dimensions as required for a particular application.

In addition, in a preferred embodiment the fibre is drawn from a monolithic holey preform (rather than a stacked preform), thereby providing further control and stability. Moreover, no doping is required to create guiding cores.

BRIEF DESCRIPTION OF DRAWINGS

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a microscope image of the cross section of a microstructured polymer optical fibre;

Fig. 2 illustrates an imaging experiment utilising a microstructured optical fibre according to the present invention;

Fig. 3 is a CCD camera image of the exit face of a fibre subjected to uniform illumination (left image); and a CCD camera image of the exit face of a fibre which has been illuminated with an image of the letter "C" (right image); and

Fig. 4 is a CCD camera image of the exit face of the fibre demonstrating an anti-guiding mode of operation.

DETAILED DESCRIPTION OF THE INVENTION

The various aspects of the present invention will be further described by way of the following example and with reference to the accompanying drawings. Whilst the fibre referred to in the following example was fabricated from polymeric material, it is to be noted that the principles underlying imaging capabilities are not specific to polymeric fibres, and other suitable material may be used.

A range of different fabrication methods can be used to make microstructured polymer optical fibre ("mPOF") preforms. In addition to the capillary stacking technique, as is traditionally used for glass PCF, polymer preforms can be made using techniques such as extrusion, polymerisation in a mould, drilling or injection moulding. These methods provide advantages over bundling or stacking, since the hole pattern, size and spacing can be altered independently and no interstitial holes are created within the lattice. In addition, the creation of non-circular holes becomes relatively straightforward.

For the fabrication mPOFs that are presented in the following example, commercially available extruded polymethylmethacrylate (PMMA) rods of 80 mm diameter were used, which has a glass transition temperature Tg = 115°C. A hole structure was drilled into an annealed PMMA cylinder of 80 mm diameter and 65 mm length using a computer-controlled facility, which is based on a programmable CNC mill optimised for mPOF preform fabrication. This provides complete control over the

relative positioning and sizes of the holes. When required, the holes can be positioned very close together, leaving an inter hole wall thickness as thin as 0.1 mm.

The mPOF preform was drawn in a two-stage process. In the first stage, the 80mm diameter structured preform was heated and stretched to a length of ~2 metres to reduce the outer diameter from 80 mm to about 12 mm.

In a second stage, the 12 mm diameter preform was drawn to fibre on a separate computer-controlled polymer fibre draw tower. Fibre was drawn at a rate of 4 m/min at a constant tension of around 100 grams and a 'hot-zone' draw temperature of ~160°C. The resulting mPOF structures, such as that shown in Fig. 1, are maintained over lengths of 100 m. Fibres are generally drawn to an external diameter of 200 microns, with a fibre diameter uniformity of ± 1 micron achieved by utilisation of a well-tuned feedback control loop between the capstan speed and the fibre diameter monitor. A preform sleeving technique has been developed to provide fibres with a larger outer diameter whilst maintaining the same dimensions for the internal structure of the fibre, when required.

Referring to Fig. 1, a microscope image of the resulting microstructured polymer optical fibre is shown. The diameter of the fibre is 800 micron and the cross-section includes an array of evenly spaced air holes (112 holes in total at spacings of 42 microns) which provides the imaging function by guiding in between the air holes (solid cores), by antiguiding in the air holes, or both. A second, similar fibre was fabricated from the same preform with 250 micron diameter and 15 micron hole spacing.

To demonstrate the imaging capability of the solid-cores, a metal screen with a C shape cut out is placed in front of a white light source. Fig. 2 depicts an experiment wherein a metal screen with a cut out in the form of the letter C cut out was placed in front of a white light source. The screen was imaged onto one end of the fibre by means of a small lens (f~5mm). The fibre transmitted this image over its 42 cm length and the opposing end face of the fibre was imaged onto a CCD camera with a 10x microscope objective.

Fig. 3 illustrates the CCD camera image of the exit face of the fibre for uniform illumination (left) and the CCD camera image of the exit face of the fibre with the letter C screen in front of the white light source (right). It can clearly be seen that the cores in between the air holes have guided the image in a coherent way. This image is maintained under fibre bending, down to a bending radius of approximately 3 mm,

beyond which the transmission losses become significantly higher (for the 250 micron diameter fibre).

Referring to Fig. 4, a CCD camera image of the exit face of the fibre is illustrated which demonstrates the second mode of operation of the fibre (antiguiding). This experiment was identical to the previous one, with the exception that it was performed with a 20 cm long piece of the 800 micron diameter fibre. The image on the left shows the result for uniform illumination. A slight blue colouration of some of the cores is common for the antiguiding mechanism (blue wavelengths are guided more efficiently in antiguides). The image on the right shows the result for imaging of a pinhole. When the pinhole is moved around, the bright spot in the image moves accordingly, demonstrating that the air channels act as individual guiding cores.

As mentioned above, one possible application is in relation to chip-to-chip connections. For high-speed computer chips that are operating at very high frequencies, small wires that connect the chips will act as antennas, and the electronic signals sent from one chip to another at such speeds would be distorted, radiated out or lost. Also, timing and synchronisation issues become important. This can potentially be overcome by having one chip drive something like a VCSEL array (a usually square array of Vertical Cavity Surface Emitting Lasers) producing a pattern of light beams that are all (individually) modulated to carry signals. This array of light is then captured by the microstructured imaging fibre, which has cores of appropriate sizes and positions to match the VCSEL array (either solid cores, hollow cores or both). The signals and transferred to the other end of the fibre where it is read out by a detector array of similar arrangement as the VSCEL array. The fibre can either be butt-coupled to the VCSEL array, with for example each hollow channel capturing the light from one VCSEL, or some imaging arrangement with a lens or multiple lenses can be placed in between the VCSELs and the fibre end.

A further possible application of the present invention is in relation to ear implants. Ear implants (such as developed by Cochlear Pty Ltd) consist of a fine electrode embedded in silicon which is to be implanted into the cochlear in order to directly stimulate the nerves and thereby recover some sense of hearing. One issue with implanting ear implants is that they are inserted without any visual image of the channel of the ear. Sometimes obstructions are encountered, and without a visual image of the obstruction, it cannot be determined how to get around it, or whether it is safe to go

through it. Advantageously, the imaging mPOFs created by the present invention can be of such small dimensions, that they would be suitable to be incorporated into the silicone ear implant, and thereby provide an image from the tip of the implant as it is inserted.

Although the invention has been described with reference to specific examples it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

DATED this 24th day of November, 2003
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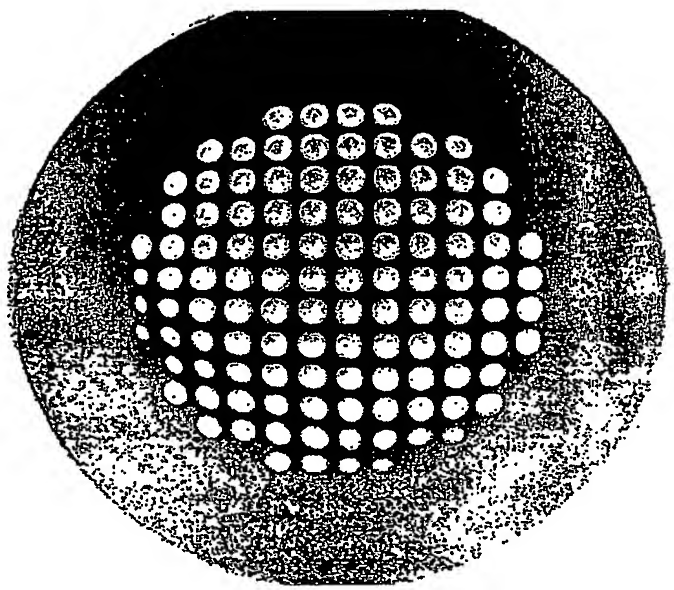

Fig. 1

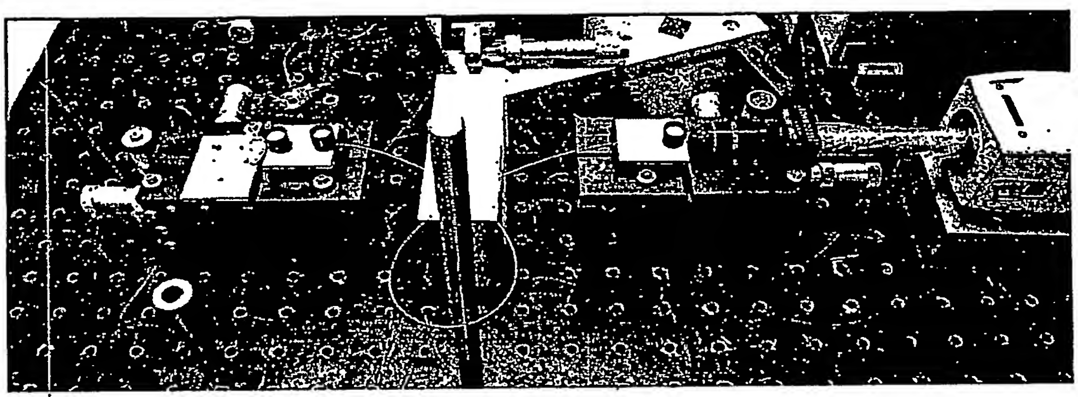

Fig. 2

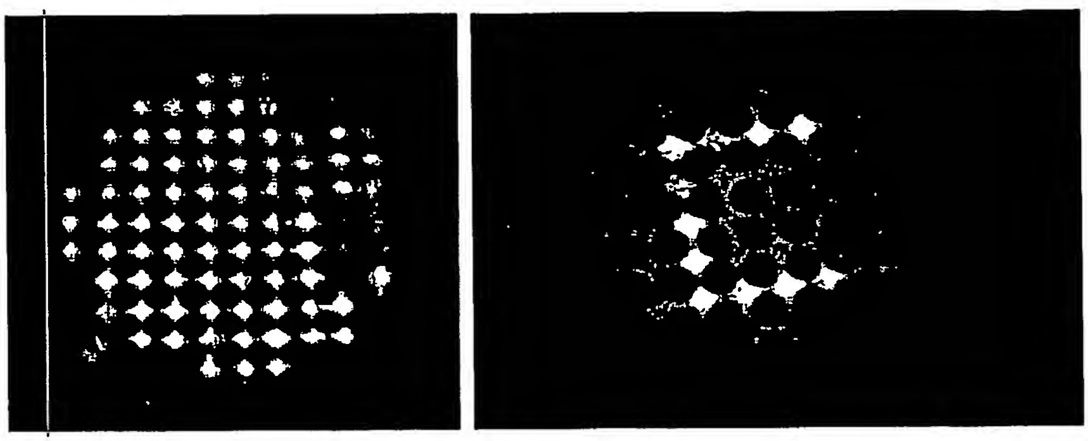

Fig. 3

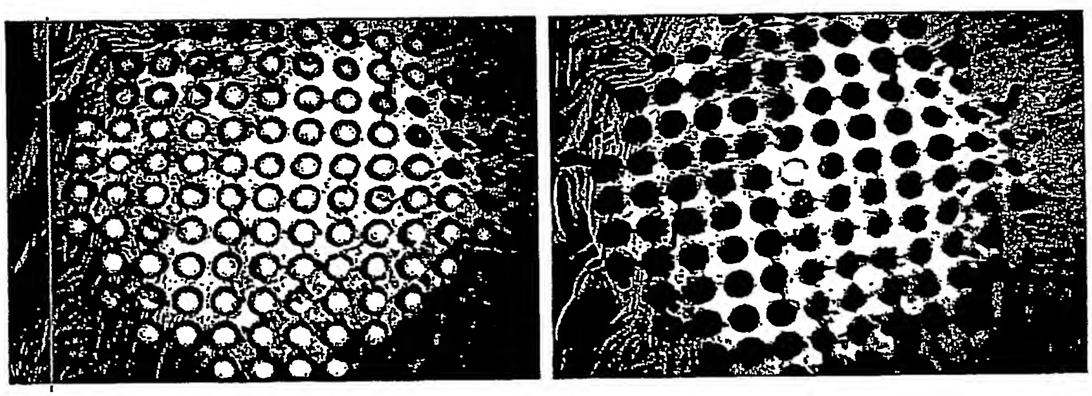

Fig. 4

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